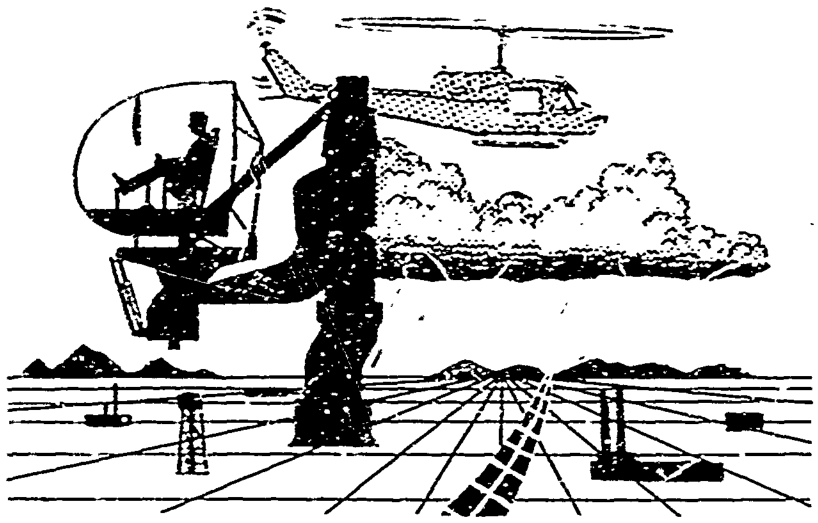
JANAIR

JOINT ARMY-NAVY AIRCRAFT INSTRUMENTATION RESEARCH

TECHNICAL REPORT
NO. D228-100-011



FINAL TECHNICAL REPORT, JANAIR CONTRACT 4429(00)

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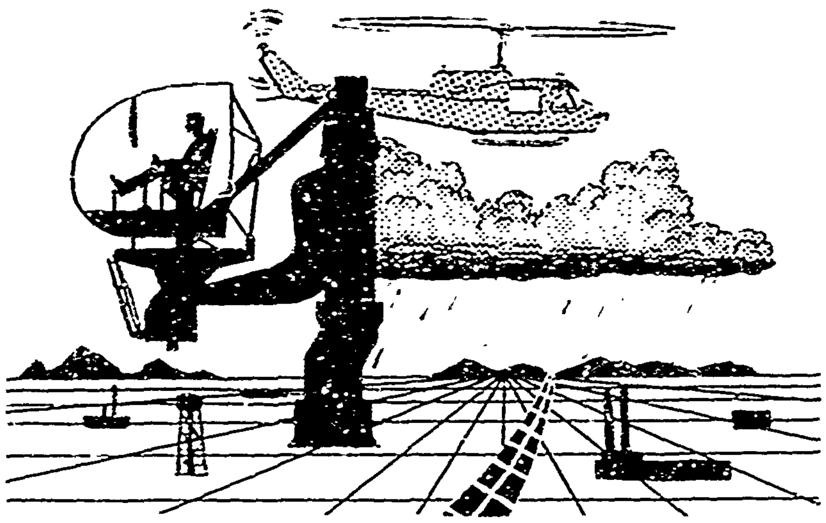

FINAL TECHNICAL REPORT, JANAIR CONTRACT 4429(00)

BELL HELICOPTER COMPANY

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JOINT ARMY NAVY AIRCRAFT INSTRUMENTATION RESEARCH

FINAL TECHNICAL REPORT, JANAIR CONTRACT 4429(00)

Technical Report No. D228-100-011

February 1966

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Office of Naval Research
Contract Nonr 4429(00)

This report presents work which was performed under the Joint Army Navy Aircraft Instrumentation Research (JANAIR) Project, a research and development program directed by the United States Navy, Office of Naval Research. Special guidance is provided to the program from the Army Material Command, the Office of Naval Research and the Bureau of Naval Weapons through an organization known as the JANAIR Committee. The Committee is currently composed of the following representatives:

U. S. Navy, Office of Naval Research
CDR D. D. Kilpatrick

U. S. Navy, Bureau of Naval Weapons
CDR W. A. Engdahl

U. S. Army, Material Command
Mr. Len Evenson

The goals of JANAIR are:

a. The Joint Army Navy Aircraft Instrumentation Research (JANAIR) program is a research project, the objective of which is to improve the state of the art of piloted aircraft instrumentation.

b. The JANAIR Project is to be responsive to specific problems assigned, and shall provide guidance for aircraft instrumentation research and development programs.

c. The JANAIR Project will conduct feasibility studies and develop concepts in support of service requirements.

d. These efforts shall result in reports and the knowledge to form the basis for development of improved instrumentation systems, components and subsystems.

ABSTRACT

This report covers work performed by Bell Helicopter Company for the Joint Army Navy Aircraft Instrumentation Research Program under Contract Nonr 4429(00). The contract work was initiated May 1, 1964, and terminated February 28, 1966. Under this contract, studies were performed in both the flight simulator and the helicopter.

The simulator studies were oriented about improvement and information augmentation of the contact analog. They were performed in the JANAIR/Bell Dynamic Flight Simulator and examined pilot performance as a function of: (1) the use of director symbols and changes in grid texture, (2) presentation of flight information on vertical tapes, (3) the use of digital readout of flight information.

Flight studies examined the Spectocom Head-Up Display and television in flight situations in the JANAIR research helicopter. Recommendations for solution to these problems are presented in the correspondingly appropriate technical reports.

Technical reports of all researches performed under this contract have been issued and are reviewed in this document.

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I. INTRODUCTION

The scope of this report encompasses the studies performed by the Bell Helicopter Company during the period 1 May 1964 to 28 February 1966 under Contract Nonr 4429(00). The work was outlined to the JANAIR Committee in the following proposals:

299-099-232	Flight Evaluation of RH-2 Display System With Added LLL TV Capability
299-099-233	Flight Evaluation of Head-Up Displays in the RH-2
299-099-244	Evaluation of the Contact Analog Display Augmented With Numerical Information
299-099-250	Proposed JANAIR Rotary Wing Research: Display of Secondary Flight Information
299-099-015	Contact Analog Studies to Improve Performance on Basic Maneuvers.

The work performed under this contract was a direct follow-on on Contract Nonr 1760(00). Under that program enormous strides were taken in the development of the pictorial flight display concept. It was initiated with the development of a complete system oriented approach to both the display design and the engineering philosophy. Following exhaustive laboratory testing of the pictorial display concepts, specifications were written for the equipment. These displays were produced under subcontract. Flight attitude and position sensors as well as an in-flight computer were procured. The system was integrated by the Bell engineering staff and installed in the research helicopter. Feasibility tests followed.

The flight displays, both the vertical and the horizontal, were designed as research displays. Provisions were made for additional symbology which could be assigned display roles beyond the basic missions which defined the original displays. For example, two abstract symbols were provided with the vertical display, a cross and a square. No definite display assignment was made to these symbols. They could be used as director symbols, as targets, as moving indices on scales scribed on the display face or a variety of command information. Likewise, the horizontal display had an expanding and contracting circle which could provide fuel range or altitude or rate information as desired. These symbols were provided to permit the display concept to grow and the display to permit evaluation on the new concepts.

Evaluations of the contact analog, prior to this contract, examined the capabilities of pilots to perform flight maneuvers and basic navigation with the experimental displays (Abbott et al, 1964; Dougherty et al, 1963; Emery et al, 1964; and Sgro et al, 1964). These studies reported the display advantages and disadvantages. In brief, with knowledge gained from all the studies, it was possible to perform all basic flight maneuvers (basic air work and basic ground reference maneuvers) as well as fundamental navigation problems under full simulated instrument flight conditions.

Flight experience in the actual helicopter included performance of all basic flight maneuvers including hovering and touchdown maneuvers. These were reported in the popular press (Aviation Week, December 7, 1964). From these experiences, not only the advantages but the deficiencies in the displays and the system concept were revealed. Corrections for these were proposed to the JANAIR Committee. Some of them were funded on this contract. These included the deficiencies of detailed numerical readout information for altitude and airspeed, deficiencies in the lack of secondary information and the deficiencies in interpreting the contact analog itself in the hovering mode.

This contract included two studies which were aimed at expanding the IFR display system beyond the basic attitude and navigation maneuvers. These studied the addition of a low light television display to the RH-2 cockpit and an evaluation of the Spectocom Head-up Display in the helicopter flight regime.

II. EXPERIMENTAL APPARATUS

This section contains the engineering description of three systems: the simulator, the RH-2 television installation and the Spectocom Display which was installed in an Army H-13K.

A. Simulator Apparatus

The dynamic platform simulator has been described in the previous JANAIR reports under ONR Contract Nonr 1670(00) (Norden 1963, Willis 1960 and 1962). It is shown in Figure 1 with the side by side cabin mounted on the platform. The cockpit incorporates the JANAIR vertical display, a full set of dual controls, a sound system and full communication equipment with the experimenter's console. Figure 2 shows the experimenter's console as used during this contract. The equations of motion were identical to those in the previous studies (Willis 1962). Figure 3 presents three types of augmentation of the contact analog to test the addition of digital data. The photographs show: (1) digital readout windows, (2) moving vertical tapes for altitude and airspeed with fixed pointers and the indication of heading superimposed on the horizon and (3) fixed tapes with moving indices.

One study examined the flight display modified to present a series of additional data displays to help in improving hovering, touchdown and takeoff maneuvers. Figure 4 shows the additional symbology configured for this study. This included two vertical linear scales, a horizontally moving pointer and a cross and square within the display itself. Assignment of rate or position was made to these symbols for lateral, fore-aft and vertical movement.

Figure 5 shows the "T" texture incorporated into the contact analog to assist in providing a more definite altitude index. The size of the "T's" increased with descent until they joined to form a solid square grid when the touchdown altitude had been achieved. One study examined the ability of pilots to use the contact analog while time sharing with other instruments. Figure 6 is a photograph of the instrument panel showing installations of the vertical tapes with the contact analog. The tapes are adjacent to the vertical display in the upper photograph and ten inches away in the lower photo.

B. Flight Apparatus

The RH-2 was used in basically the same configuration as in the previous contract. Figure 7 shows a picture of the RH-2 hovering. The fully enclosed left side of the cabin may be seen with the black hood in place. Figures 8 and 9 show the installation of equipment in the aft cabin of the RH-2. Appropriate labeling of equipment is provided.

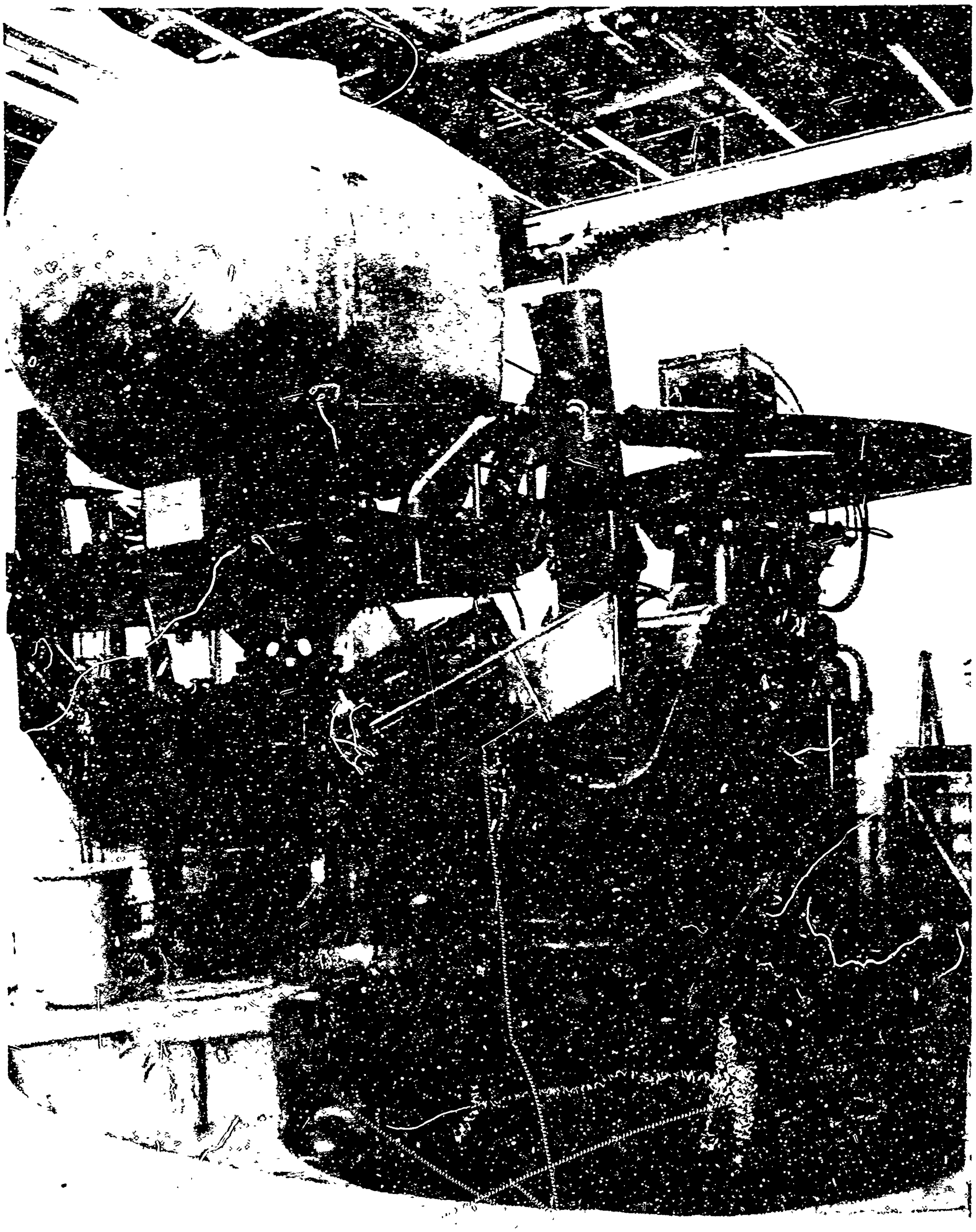

Figure 1. Dynamic Platform Simulator Showing Side by Side Cabin Mounted on the Platform

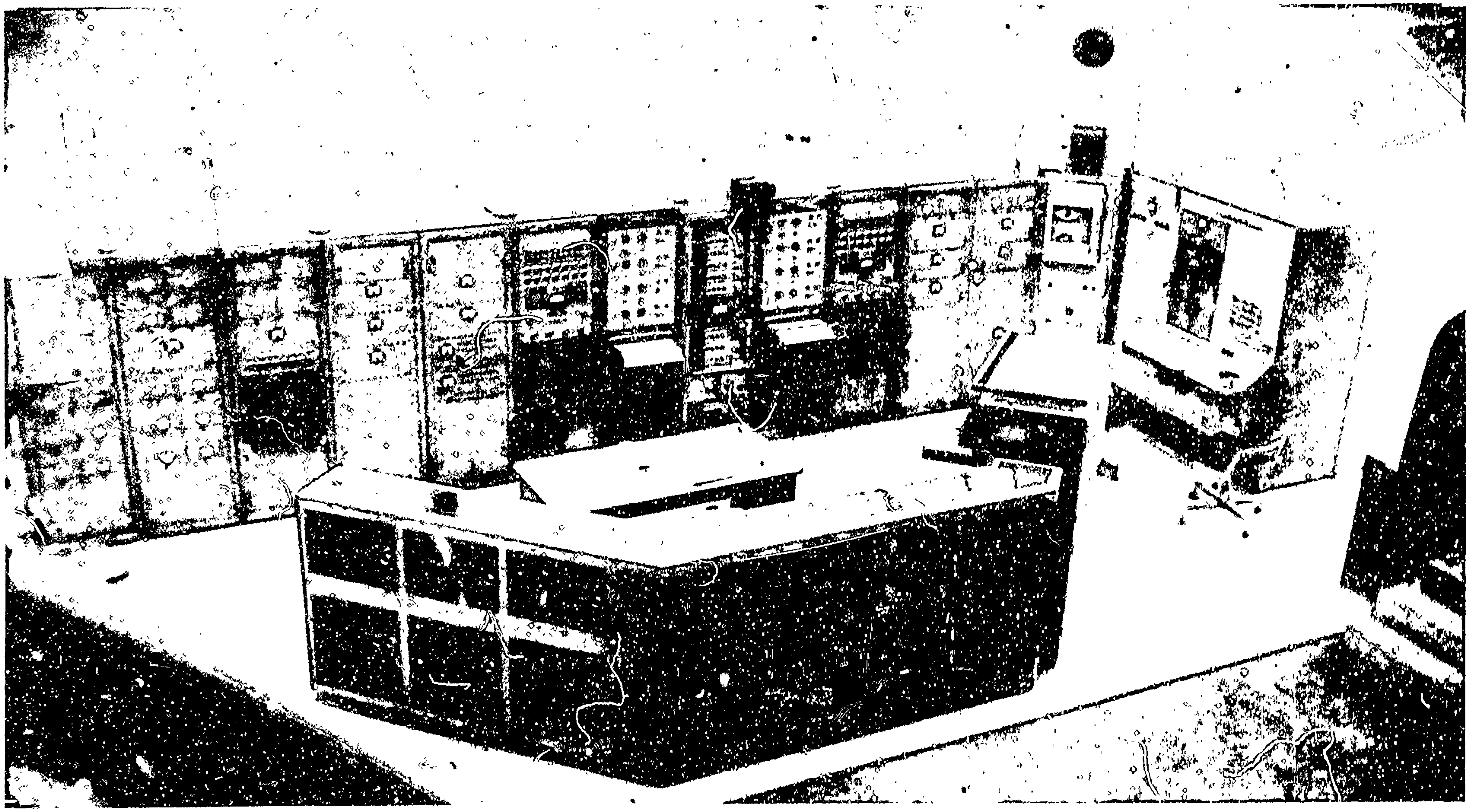

Figure 2. Photograph of the Computer and Experimenter's Console in the Flight Simulation Laboratory

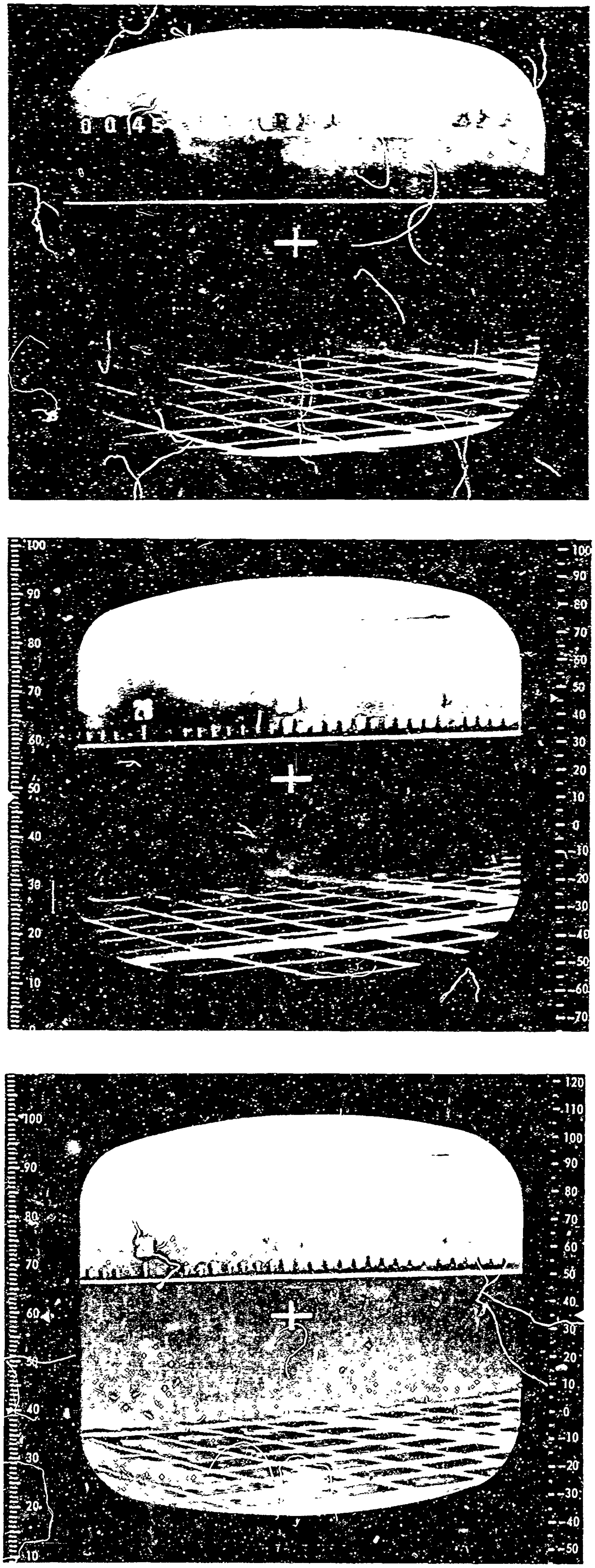

Figure 3.

Photograph of the Contact Analog Display Showing Configuration Used to Test Digital Readouts Displayed on Counters, on Moving Pointers with Fixed Linear Scales and on Moving Scales with Fixed Linear Pointers.

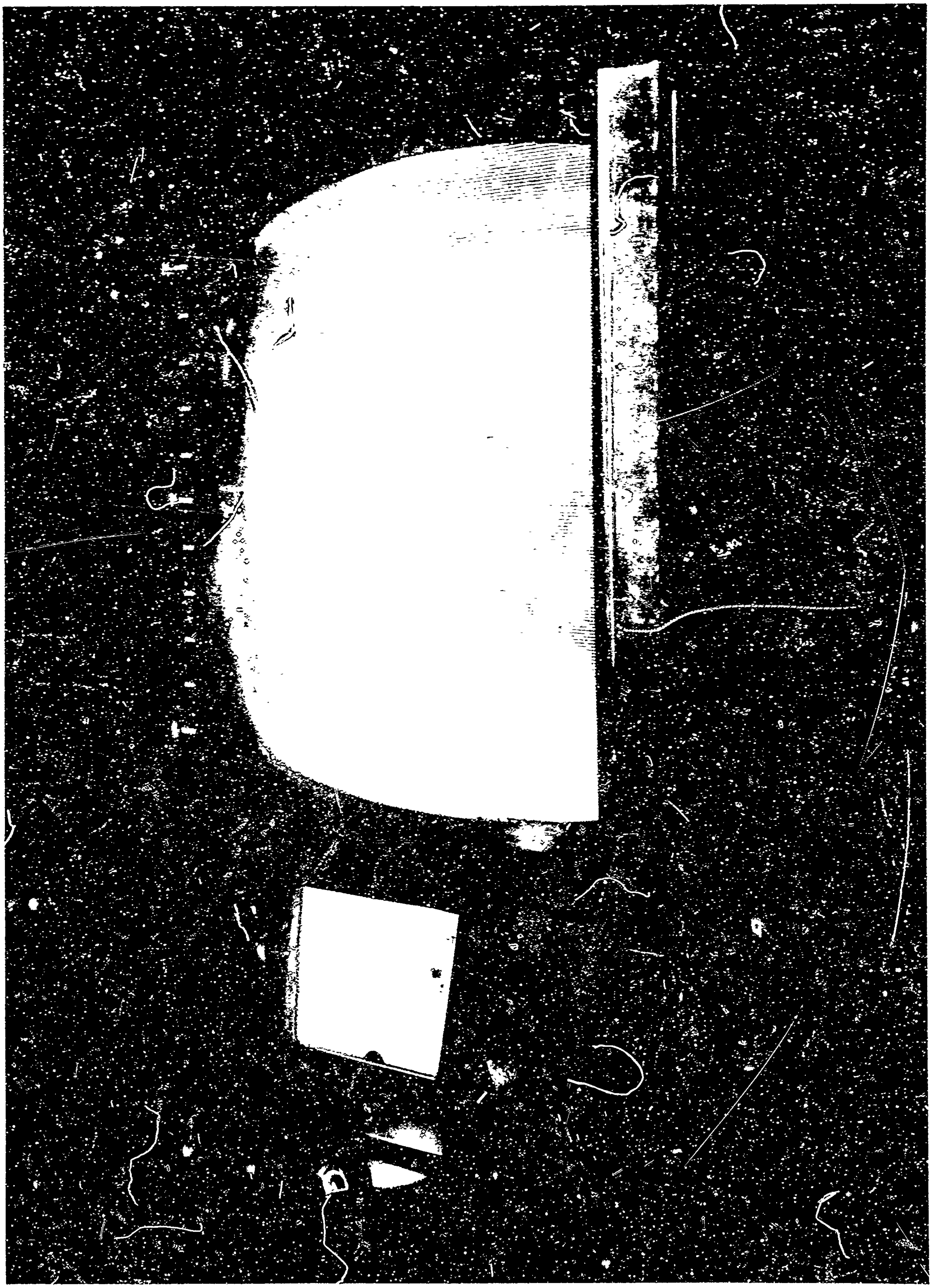

Figure 4. Photograph of the Contact Analog Mounted in the Dynamic Platform Cabin Showing the GPI at the Bottom of the Display, the Cross and Square Symbols, Vertically Mounted Linear Scales on Either Side of the Display and a Horizontally Mounted Pointer Instrument Below the Display

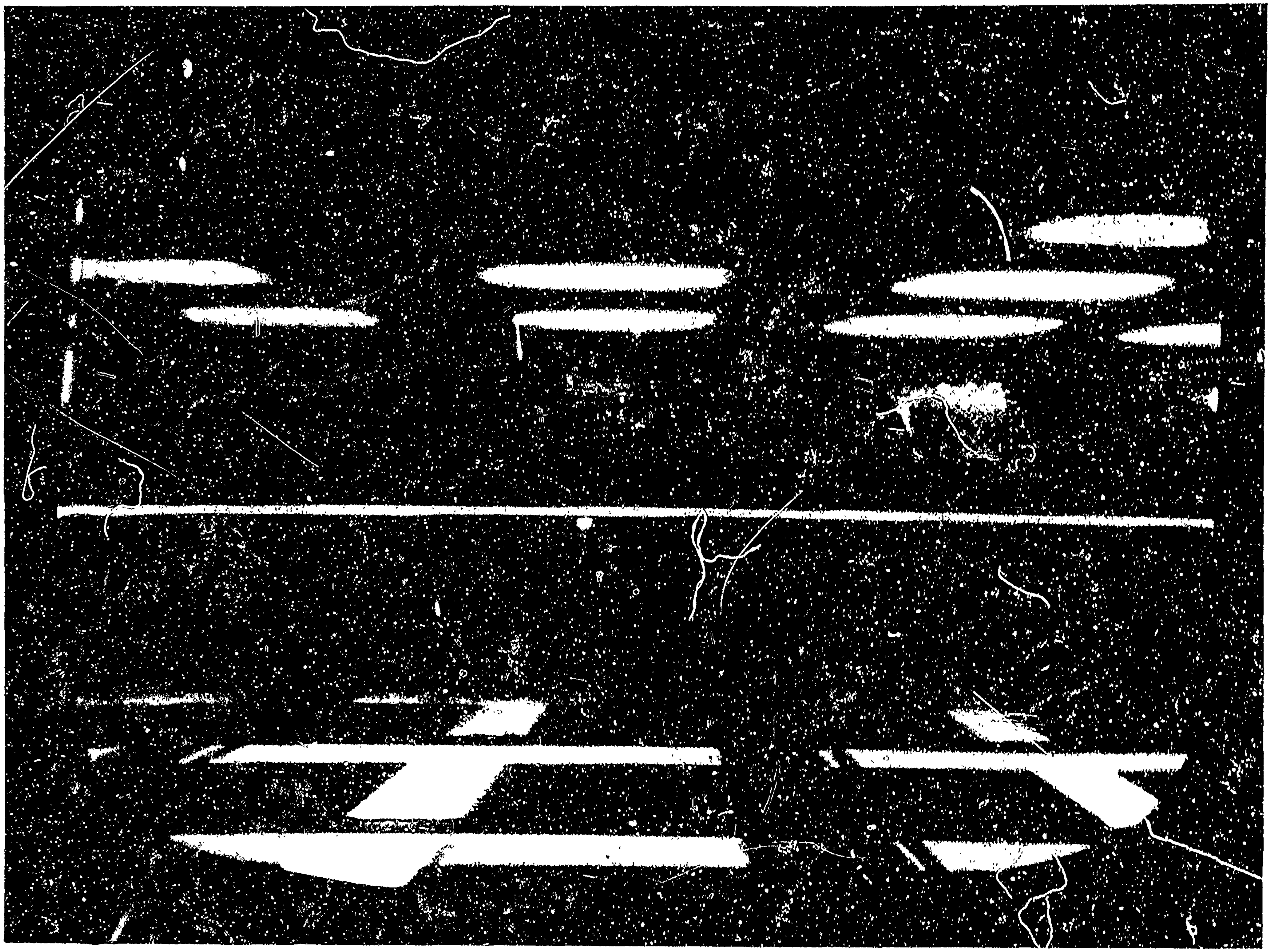

Figure 5. Photograph of Experimental Texture Pattern Used With the Contact Analog. The "T" Elements Change in Size With Altitude, Increasing With Descent Until They Join to Form Grid When Touchdown Altitude is Achieved. Displayed Altitude is Approximately Ten Feet.

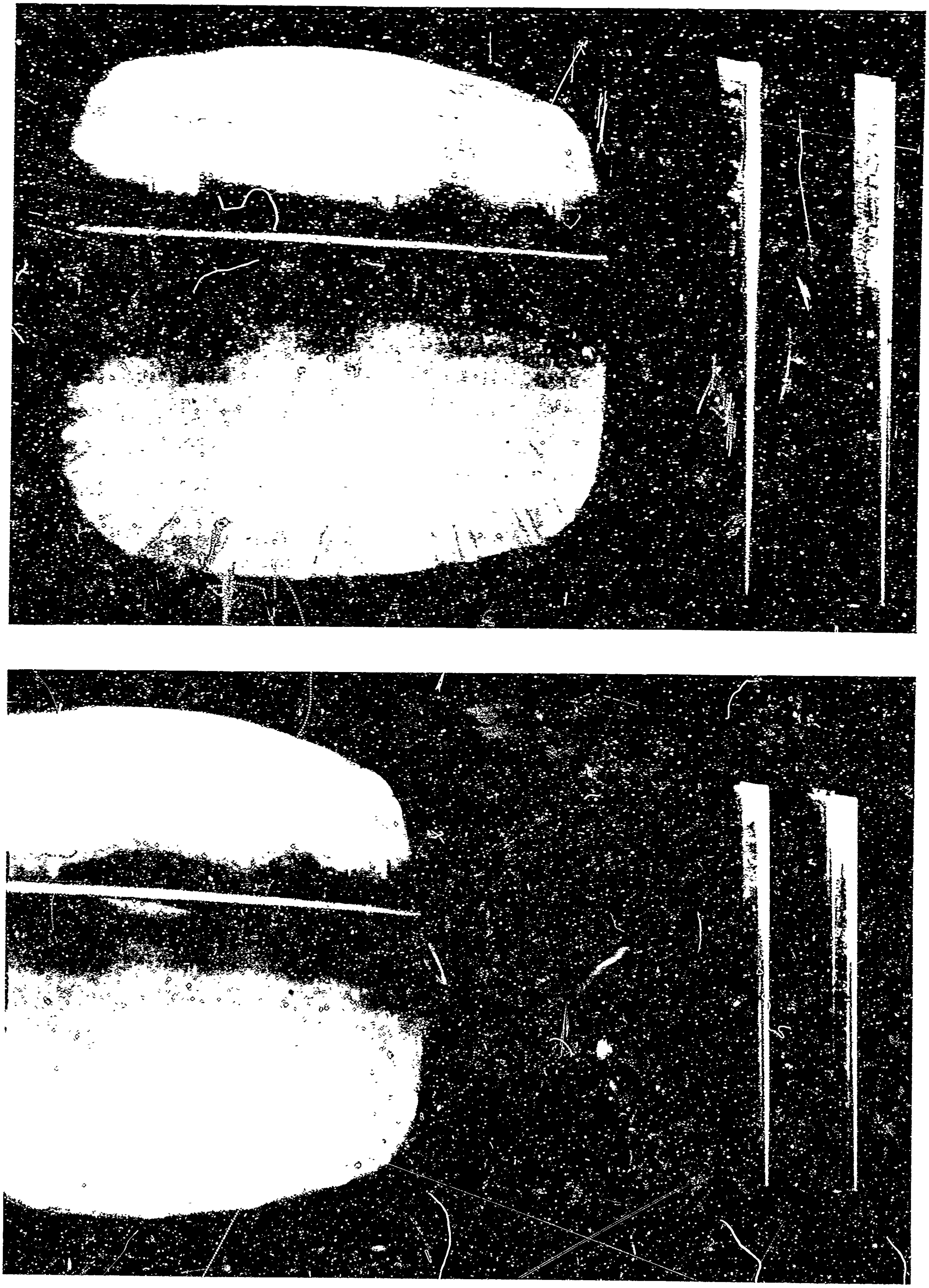

Figure 6. Photographs of Installation in Simulator of Vertical Tapes in Two Locations Within the Cockpit. Above Three Tape Type Instruments Are Mounted Adjacent to the Contact Analog. Below They are Located Distal to the Display.

Figure 7. Photograph of Bell Helicopter UH-1 Designated JANAIR RH-2 Showing Instrument Flying Hood in Place

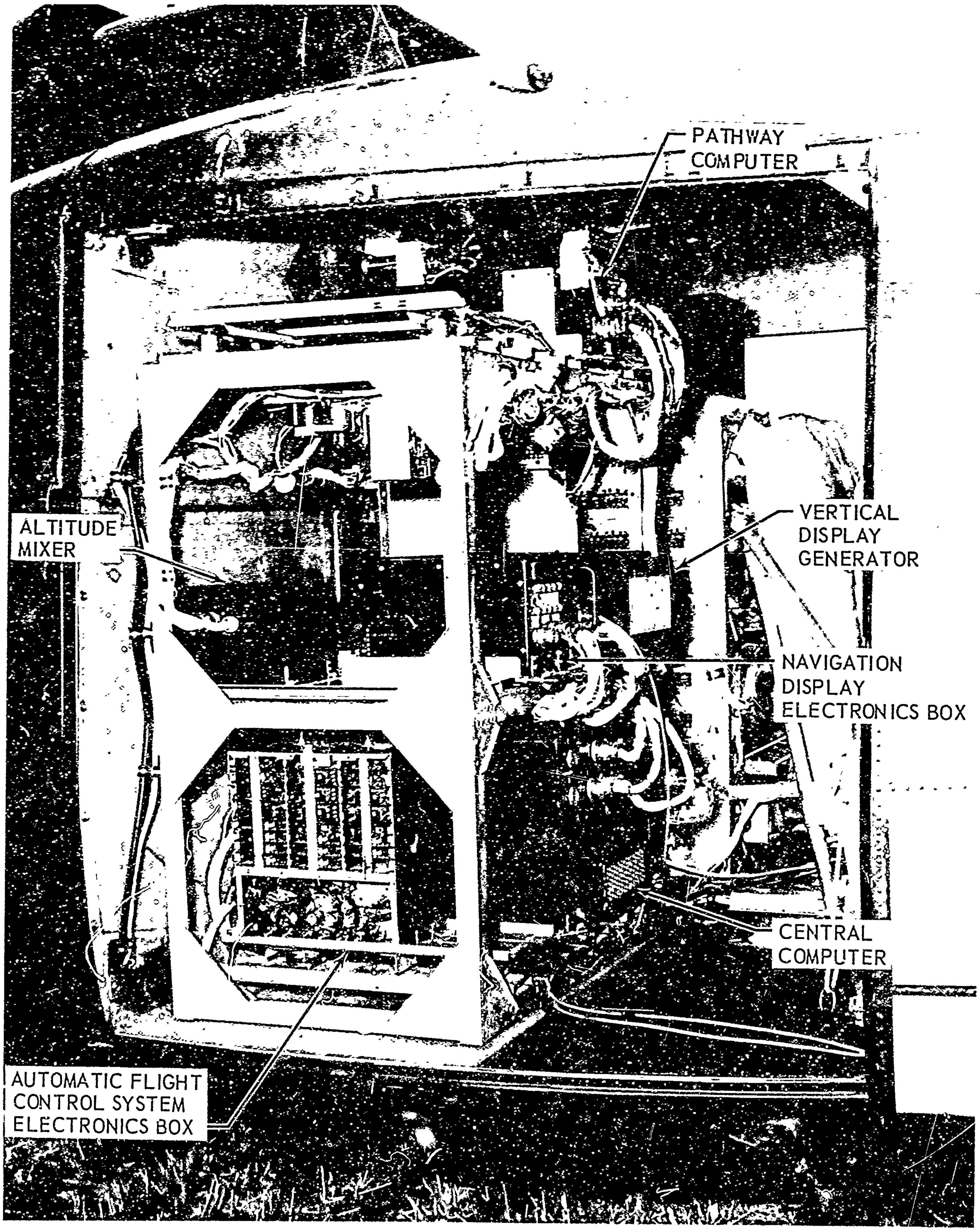

Figure 8. Photograph of Right Rear Cabin Showing Equipment as Indicated

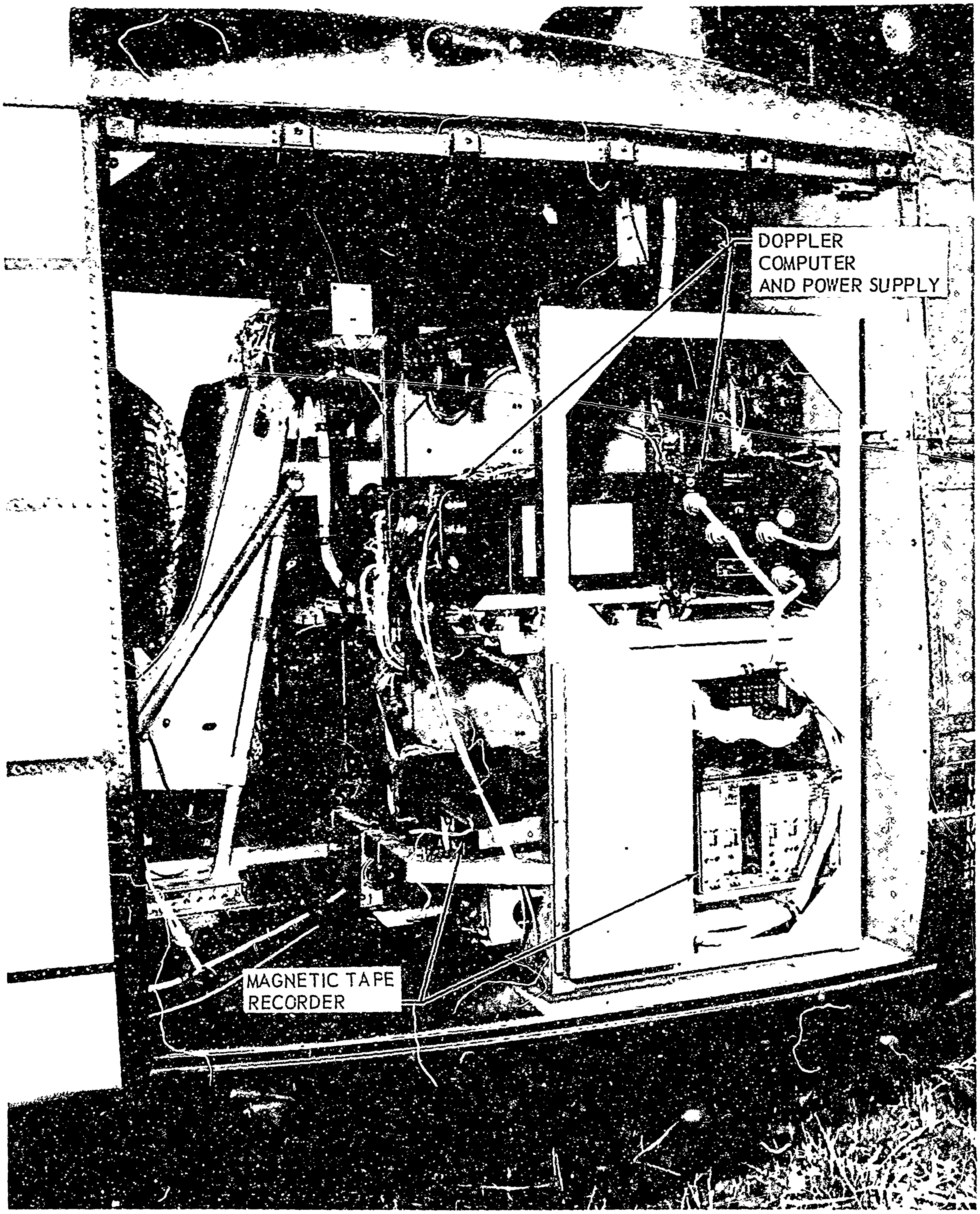

Figure 9. Photograph of Left Rear Cabin
Showing Equipment as Indicated

The installation of the television display was in the location of the contact analog. A photograph of the RH-2 cabin may be seen in Figure 10. The original low light level television provided was a Vare. This did not meet standards. An Admiral TV modified by the U. S. Army, was then provided.

A Spectocom Head-up Display was installed in a bailed Model H-13K. The Spectocom Display installation is shown in Figure 11 on the right side of the helicopter. A control panel for that display is mounted directly below the display. (See Ref. 5, 6 and 7.)

C. Data Acquisition Equipment

1. Data Acquisition System

A block diagram of the analog-digital data handling system is shown in Figure 12. This system was compatible with both the simulator and flight test data recording systems and with the 1401-7040 computing system at the Bell Data Processing Center.

Analog magnetic tapes from flight test or simulation were loaded onto the magnetic tape playback unit. These tapes were then read into the central processor using machine language programs operating in real time. The analog data was digitized, formatted, edited and written on the two million character disk files. These disk files were then sent to Data Processing, where the data were written on magnetic tape and analyzed. A photograph of the Data Facility and its location adjacent to the simulator is shown in Figures 13 and 14.

2. Program Support

A complete set of programs was available to support both the simulator and flight test recording systems. These programs were general in nature in that they could be applied to the data from any experiment. In a sense, these programs reprogrammed themselves to fix the particular experiment of interest.

In actual operation, the appropriate set of programs was loaded into the memory of the 1710 along with seven data cards specifying the control information connected with the experiment. The program read these data cards and modified its addresses and instructions. After completing the changes, a message was typed out for the operator telling him that the set of programs were now ready for data.

When all the data had been written on magnetic tape, the tapes were placed on the 7040. Statistical analysis was then performed and printed or plotted output obtained.

3. Flight Test

The data recording system used during flight experiments was portable. It was similar to its simulator counterpart and

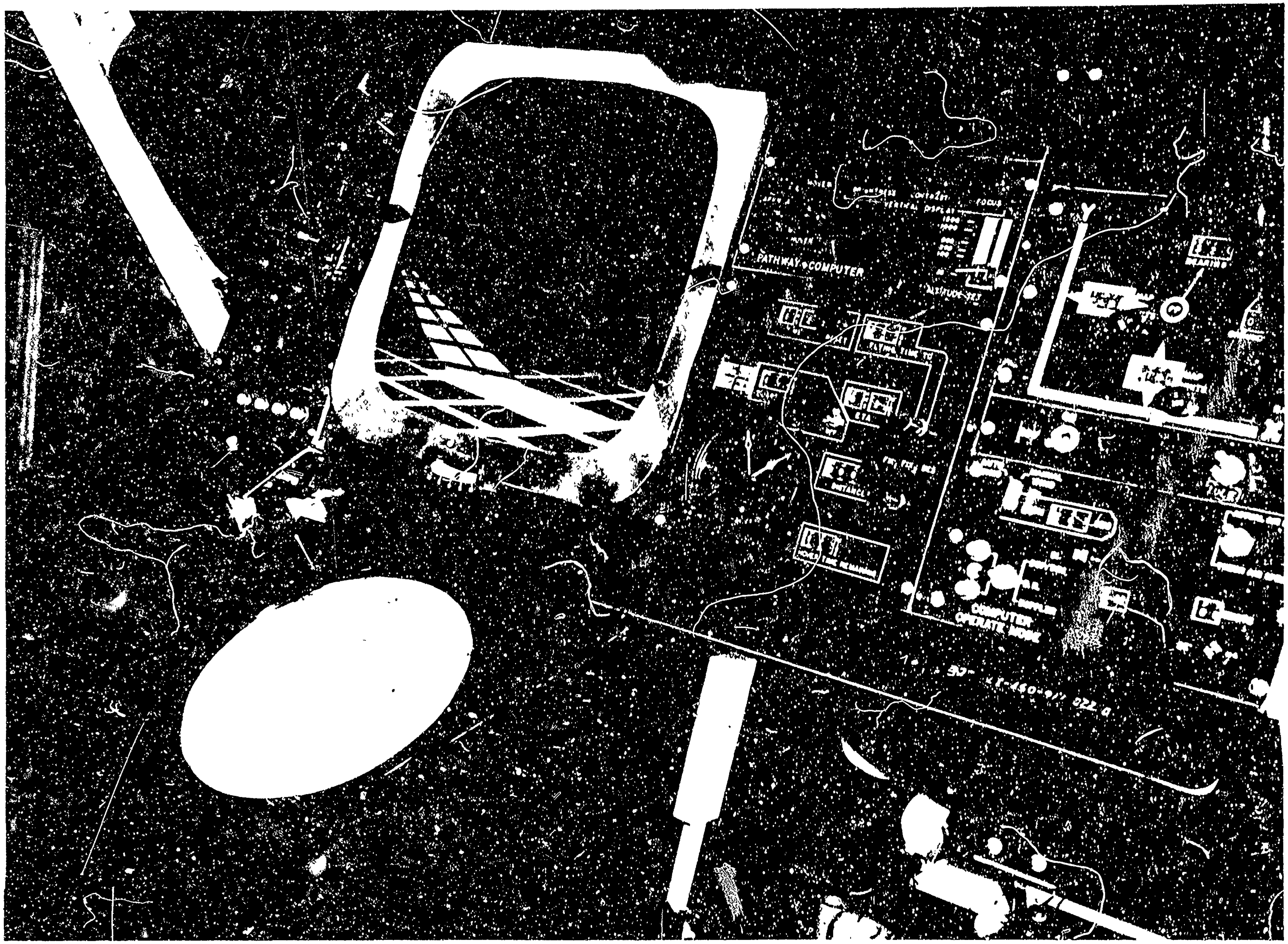

Figure 10. Picture of RH-2 Cockpit With Photograph of Contact Analog in Place Over Display

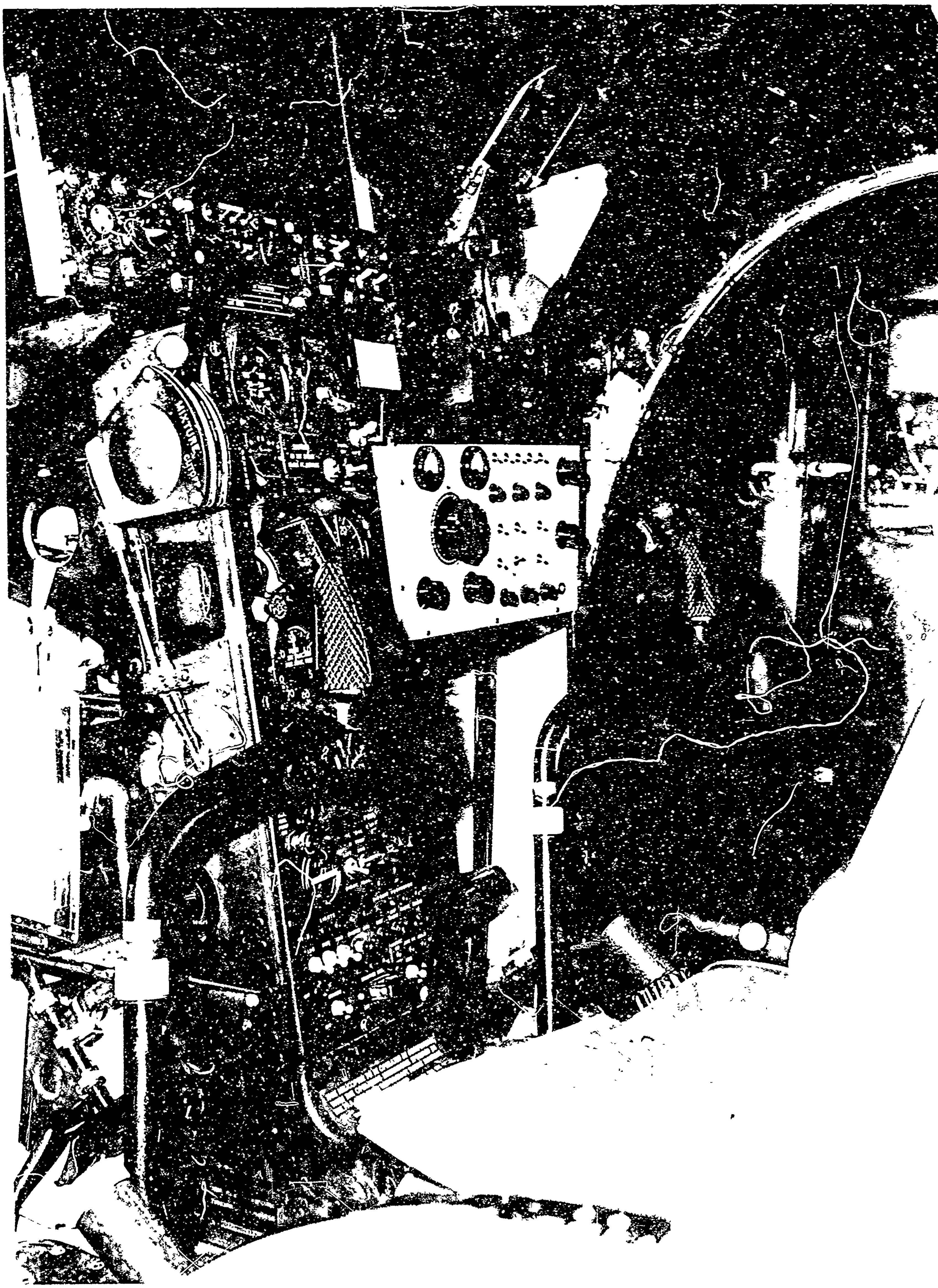

Figure 11. Photograph of the Bell Helicopter H-13K Cockpit Showing Installation of the Spectocom Viewing Unit and Control Unit on the Right Side of the Cockpit

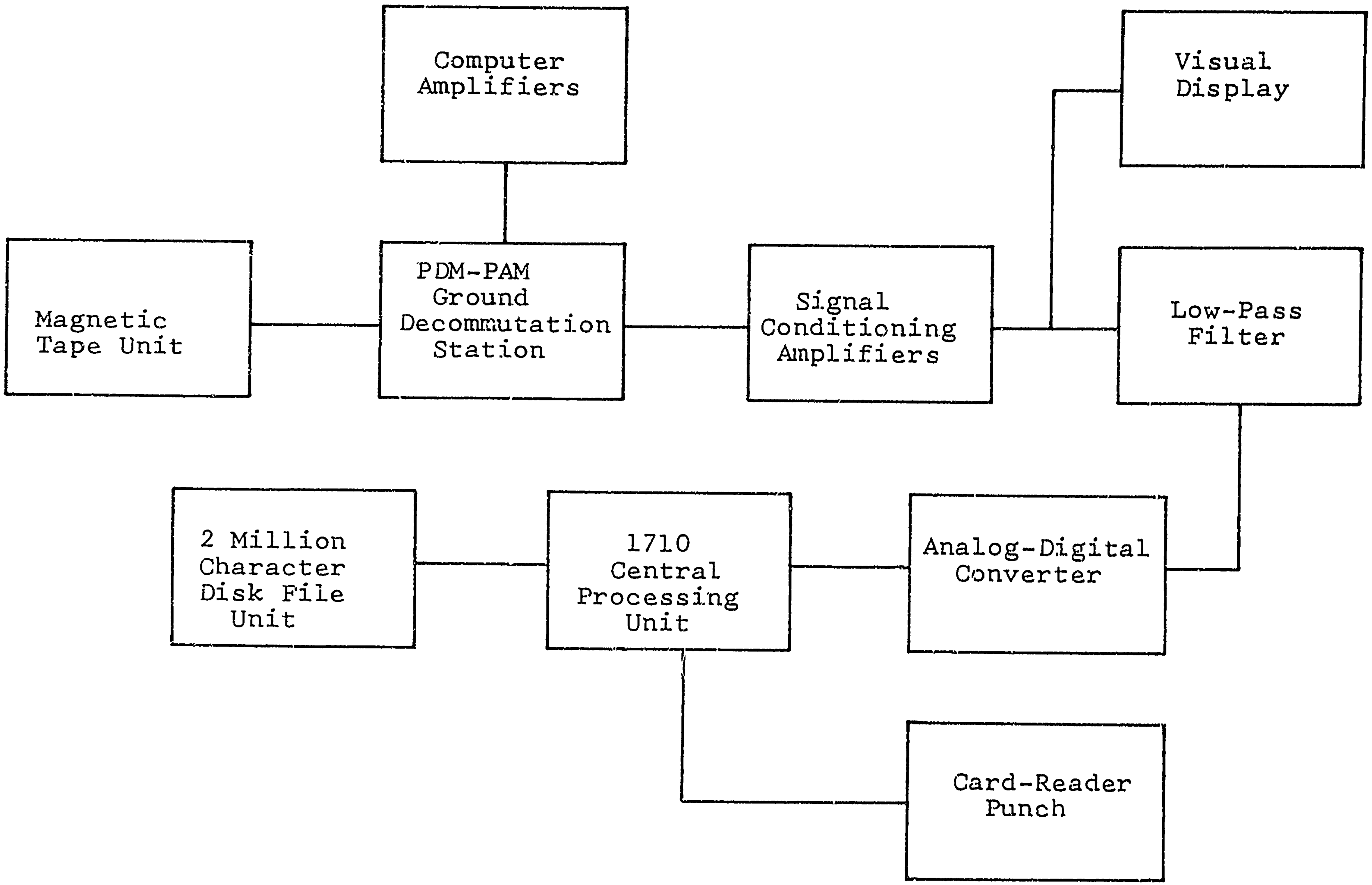

Figure 12. Data Acquisition

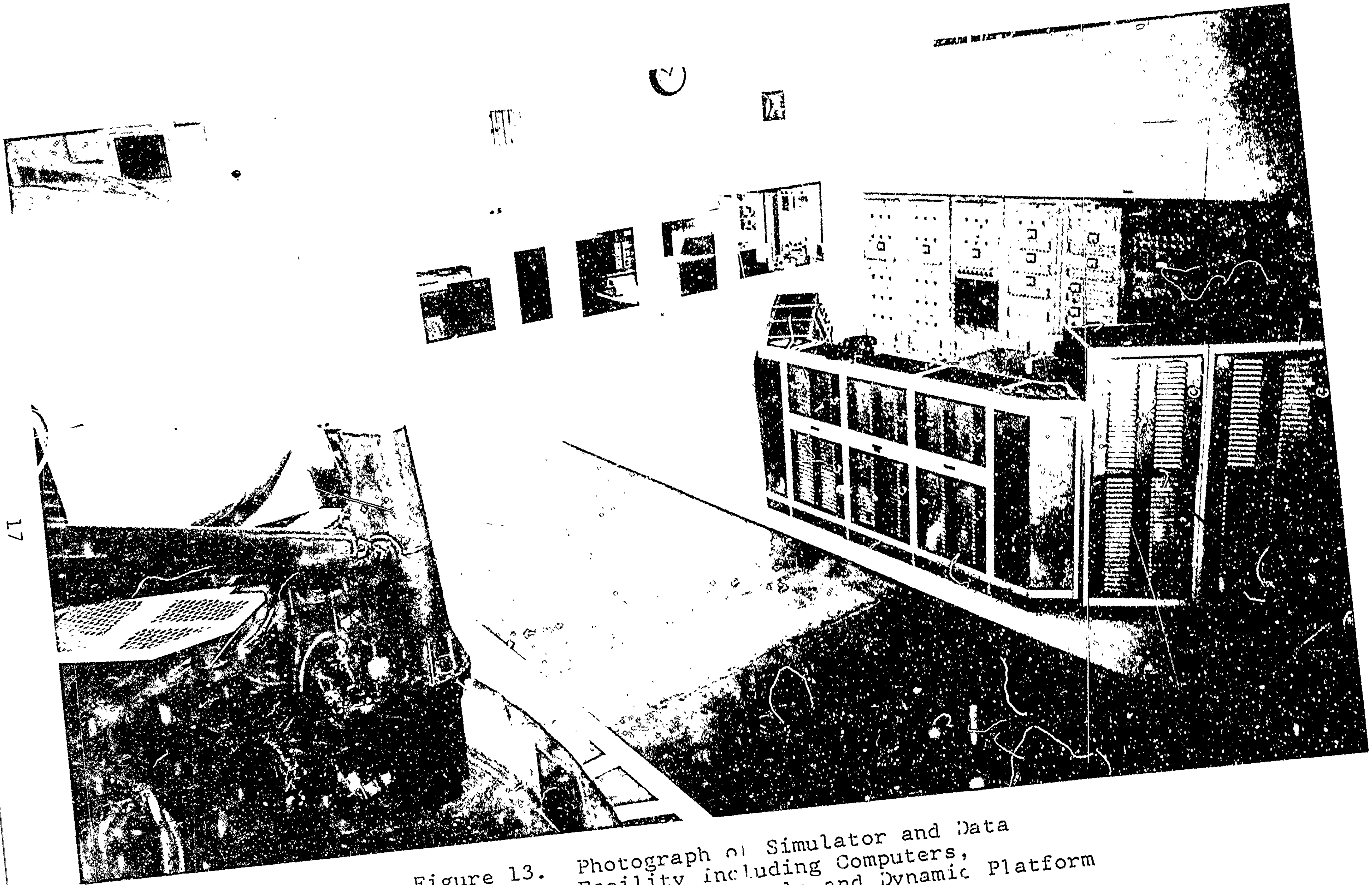

Figure 13. Photograph of Simulator and Data Facility including Computers, Operators Console and Dynamic Platform

Figure 14. Photograph of Data Facility Showing Computer Decommutation Equipment and Tape Playback Unit

required only 115V 60 cycles, 26V 400 cycles, and 28V D.C. power from the flight vehicle. A block diagram is shown in Figure 15.

Data from sensors, computers and other devices were first converted to a D.C. signal. The signal was then conditioned in a bank of attenuators and commutated using a 30 channel electronic commutator. This time multiplexed signal was in pulse duration form. The data signal, along with a parallel voice channel, was then recorded on magnetic tape. Each tape was capable of holding up to 144 minutes of data.

The voice channel recorded all communication which took place in the ship. Information from the control tower was also recorded on this channel. This channel was also used to record any identification information or performance information that might be useful in analysis.

4. Simulator

An automatic data recording system was installed at the flight simulator. A block diagram of the system is shown in Figure 16. The system was implemented so that it could provide both on line quick look data and full recording capability. Quick look data was provided on the Sanborn channels, X-Y plotter, and integrator counter channels. This data allowed visual monitoring during a maneuver and gross numerical analysis immediately following pretest or training.

Quick look and plotted information were also recorded during the experiment. A total of 24 integrator counter circuits could be hand wired to supply information on performance, trial time, etc. Twenty-four channels of Sanborn information were available for simultaneous recording along with an X-Y plot of selected variables.

Forty-five channels of information were recorded for automatic data analysis. These data were multiplexed on a magnetic tape along with a voice channel. The voice channel recorded all communication between the Human Factors engineer, subjects and the electronics engineers monitoring the equipment.

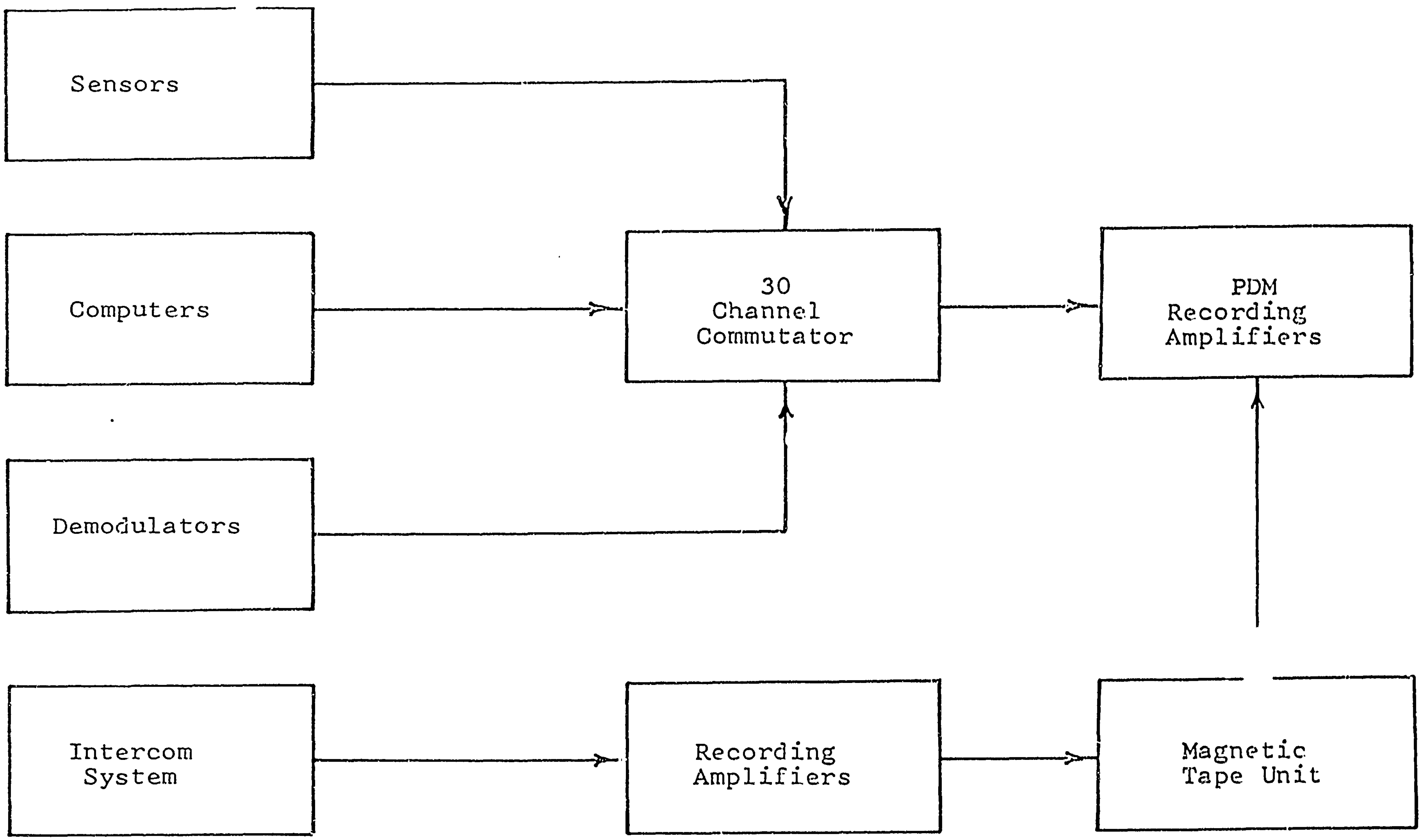

Figure 15. Portable Recording System

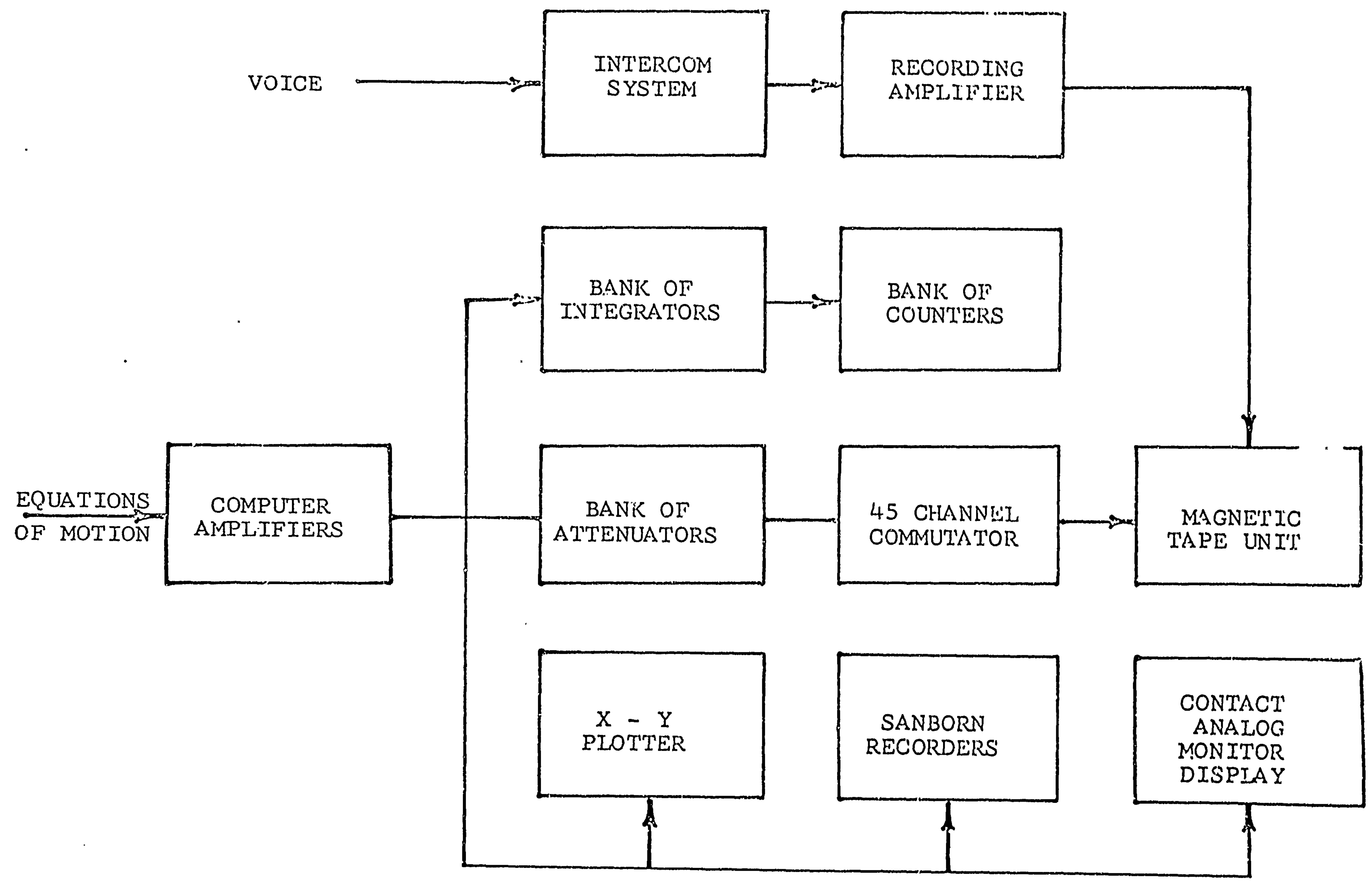

Figure 16. Flight Simulator Data Recording System

III. EVALUATIONS - SIMULATOR

The simulator evaluations performed under this contract are reported in the following studies:

Emery, J. H.

Contact Analog Simulator Evaluations: Investigations of Director Symbols, Display Alterations and the Presentation of Secondary Flight Information. Bell Helicopter Company JANAIR Tech. Report D228-420-008 (in press)

Emery J. H.

Numeric Augmentation of Grid Plane Encodement. Bell Helicopter Company JANAIR Tech. Report D228-420-007 (in press)

A brief review of the findings of these studies funded in this contract is included in this report.

Investigation of Display Alteration (D228-420-008)

This study incorporated three experimental evaluations of techniques aimed at improving hovering and touchdown performance using the basic concept contact analog display. Previous ANIP/JANAIR studies found and reported a perceptual difficulty in identifying fore-aft translational movement and vertical movement during slight deviations from hovering flight. This difficulty has been observed in contact flight (with a limited field of view), in the simulator (Abbott et al, 1964), in flight with a television display (Elam, 1964) and in IFR flight with the contact analog (Curtin, in press). The hypothesis of the studies funded under this contract was to alleviate this perceptual problem by separating the visual cues for fore-aft and vertical movement. One technique studied replaced the square grid with one of T elements in which the arms of the T extended with altitude changes, thereby abstracting altitude cues from the combined altutude translation cues presented in real world movement. A second study augmented the display with linear scales. These displayed combinations of position and rate information and tested them with lateral, longitudinal and vertical movement. A third study examined a variety of techniques to improve hover. These included increasing the texture element by decreasing the size of the basic grid squares, quickening the basic grid in terms of translational movement, adding numeric data for rate and position and finally doubling the field of view.

The study of the T texture on the basic grid, compared with the control condition of the 12-foot square texture element, revealed that the only performance measures which indicated differences were altitude and fore-aft error. Less altitude error was indicated when the pilots were using the basic grid and greater error

in fore-aft position. A picture of the experimental T grid may be seen in Figure 5.

The study which examined five combinations in which linear tapes indicated position and rate of selected parameters revealed statistically significant differences for only one performance measure. This was fore-aft position at touchdown. The best condition as indicated by this score was one in which the grid did not change with altitude but a vertical position index moved over a scale representing the ten feet of altitude before touchdown.

The third study, examining hovering performance on five experimental displays, revealed that, in general, the superior display for hover position control was the basic grid with increased texture elements representing six-foot squares. The worst condition in terms of overall performance was indicated to be one in which the field of view was doubled.

<u>Secondary Flight Information, Display Position</u> (D228-420-008)

This study was designed to obtain some answers with regard the position of additional, or secondary, information (as opposed to the primary flight information displayed on the contact analog), the rate at which secondary displays of the vertical tape type should move and the effect of information type on ability to control secondary information (i.e., relevance of the data to the basic flight displays).

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The equipment, seen in Figure 6 , shows two installations. One is adjacent to the contact analog and the other ten inches to the right in a position in the center of the cockpit where such displays would be time shared between two pilots.

The scores were obtained for control of altitude, airspeed, heading and control of the auxiliary or non-relevant display.

Results indicated that (1) the location of the secondary and auxiliary displays was not effective except for control of altitude, (2) the rate of movement of the secondary displays was effective in all performance measures except heading, and (3) the task (either a cruise or terrain following) was effective only in control of altitude.

<u>Numeric Augmentation of Grid Plane Encodement</u> (D228-420-007)

Three methods of augmenting the basic grid plane of the contact analog were tested. Photographs of these may be seen in Figure 3. Method A augmented the basic grid plane with direct-reading counters. Three counters were displayed across the upper portion of the screen depicting from left to right: altitude, heading and airspeed. Method B incorporated two moving pointers with fixed scales for altitude and airspeed readings. The scales were adjacent to the screen with altitude on the left and airspeed

on the right. Heading was superimposed upon the display horizon and rotated with changes in aircraft heading so that correct heading was always depicted in the center of the screen. Method C made use of two moving scales with a fixed index for depicting altitude and airspeed. Placement of the altitude and airspeed scales were on the left and right of the display, respectively. Heading was presented as in Method B.

Statistical analyses of the data have revealed that performance scores were significantly better on any of the three experimental displays tested than on the basic grid plane alone. This was true both for a level cruise task and for a simulated terrain following task. Of the three experimental conditions statistically significant superior performance was indicated for both vertical tape conditions (Method B and C) over the digital read-out displays. No differences were indicated, for the task tested, between the moving pointer (Method B) and the moving tape (Method C) type of displays.

IV. FLIGHT EVALUATIONS

Two flight studies were conducted under this contract. They are detailed in two JANAIR technical reports:

Curtin, J. and Emery, J.
A Helicopter Flight Evaluation of a Head-Up Display, Bell Helicopter Company JANAIR Technical Report D228-420-010 (in press)

Curtin, J., Emery, J. and Dougherty, D. J.
Flight Evaluation of the Contact Analog Pictorial Display System, Bell Helicopter Company JANAIR Technical Report D228-420-009 (in press)

A. Spectocom

The Spectocom Display was tested inflight in a study designed to determine the feasibility of using this head-up display in IFR helicopter approaches. An Army H-13K was made available for the testing. A photograph of the installation may be seen in Figure 11. It was found that insufficient heading information was presented on the display for safe control. The display was deemed unsuitable. Without a request for additional funding, a Phase II of this study was instigated. Three techniques of providing heading information were employed. One condition augmented the Spectocom with the standard directional gyro. A second employed "steering" or director symbology on the display. This index took information from a computed solution to a track intercept problem. The third condition utilized both the "steering" and the directional gyro presentation. It was found that performance was acceptable with any of these three conditions in permitting IFR helicopter approaches to a 50 ft. break-out altitude. The steering dot condition permitted greater accuracy in lateral control, but also greater performance variability.

B. Flight by Television

The television phase of this contract called for a GFE camera. A Vare system was provided but when tested, found not to meet the requirements of a night system which was to improve upon the VFR conditions. This system was returned and the Fort Belvoir modified Admiral system was furnished. This system was installed and tested and again it was found not to meet criterion. It was returned for rework. The flight tests were diverted to the testing of the daylight system.

The installation of the TV was tested in the RH-2. Television was displayed on the contact analog display and combined with the grid. A photograph of the RH-2 cockpit may be seen in Figure 10.

In one test situation the contact analog was video mixed with the television picture. They moved concomitantly. This condition was tested in a previous study performed at Bell (Elam 1964). It was found to be inadequate without the addition of a constant attitude reference. This finding prompted the current study. In the second condition, the contact analog display was always aligned with the axes of the helicopter. The television camera could move to search for information. The two images were superimposed. The third condition evolved from knowing that when the two images were superimposed the television would be difficult to interpret. In this condition, therefore, when the television was moved the contact analog image disappeared. This informed the pilot that the camera was no longer in axis.

The results indicated the use of the television and the contact analog to be supportive. The television was used on landing approach maneuvers. The particular system utilized in conjunction with the open landing areas used resulted in a poor television display. The experimental test pilots preferred to use the TV with the contact analog aligned with the helicopter axes. By this means they could verify the computed data of the contact analog. Since this was given in precise form they used it as the primary data source and the TV as supportive data. Each display tended to detract from the other when displayed together. The desirable configuration was one where the two displays could be time shared.

V. RESULTS AND RECOMMENDATIONS

The results of the simulator studies indicate certain techniques by which the contact analog display may be augmented to improve performance. They likewise provide implications for a total JANAIR cockpit philosophy. The flight tests indicate uses of direct sensed data with the JANAIR flight display and an evaluation of the Spectocom Display as a total flight display analysis.

In general, the data indicated the following:

1. The addition of numeric data for heading, altitude and airspeed improved performance over the basic grid alone.

2. The use of vertical tapes for altitude and airspeed improved performance when used with the contact analog over the use of direct digital readout of this data.

3. Little effect on performance is exhibited by placement of tape information.

4. A texture change in the contact analog, which provided smaller grid squares resulted in improved hovering performance.

5. The standard Spectocom Display was adequate for IFR helicopter approaches if heading information were added.

6. The type of data provided by the contact analog display was found to be desirable in the presence of television data, however, a time sharing arrangement should be provided where the displays could be viewed singly.

From these findings and in light of the previous JANAIR/ANIP studies, a series of recommendations may be made for the continued improvement of this display concept.

These recommendations are made in two areas: (1) to improve the display as it exists as a flight display, and (2) to examine the use of the display within the total cockpit concert considering particularly the arrangement and the operational implications.

Recommendations for continued study to improve JANAIR displays:

1. Definitive investigation of the contact analog texture elements to provide altitude data. Studies on this contract indicate at least one more altitude scale is needed to the existing vertical display.

2. Investigation of vertical tapes to be used with the JANAIR flight display system with particular reference to the rate of tape or index movement.

3. Define limits of use of field of view on pictorial displays for helicopter control.

Studies performed on this contract revealed grossly inferior landing performance using a field of view expanded to twice the visual angle of a display with a 1:1 ratio with the real world. This does not agree with data on normal flight maneuvers and indicates a probable interaction of field of view and altitudes unique to helicopter operations.

Recommendations for investigation of use of JANAIR flight displays with whole cockpit orientation:

1. Determine requirement for head-up display in helicopter flight. The study reported herewith indicates that helicopter IFR approaches can be performed with a display in the head-up position, but does not offer any index of performance using the same display in a head-down position leaving the windscreen free.

2. Determine movement relationships and ability of the pilot to retain continuous display awareness in presence of other cockpit tasks.

3. Examine full uses of contact analog with other direct sensed, pictorial displays. This contract examined some TV performance, but implications for additional TV uses (search and track and station-keeping) were not examined. Addition of symbology for cross wind performance was indicated and should be examined in the operational flight environment.

VI. SUMMARY

This report reviews work performed in compliance with Bell Helicopter Company Proposals 299-099-232, 233, 244, 250 and 015. These were funded under the Office of Naval Research Contract Nonr 4429(00) with the Bell Helicopter Company. Direct technical guidance was administered throughout the evaluation of contractual proceedings by the Joint Army Navy Aircraft Instrumentation Research committee.

Under this contract, experimental and evaluative studies were performed in the Bell/JANAIR Flight Simulator, in the Bell/JANAIR Research Helicopter #2 and in a Bell H-13K.

The simulator studies examined pilot performance as a function of: (1) the use of director symbols and changes in grid texture; (2) the presentation of flight information on vertical tapes; and (3) digital readout of flight information augmenting the contact analog. Results indicate performance on various maneuvers can be improved by altering the grid texture on the contact analog, adding digital data on flight parameters and by using vertical tapes for digital readouts of flight parameter data.

The flight studies examined the use of television with the contact analog and the feasibility of using a head-up display for full IFR landing approaches. The television studies indicated that both the contact analog and the television, although providing somewhat redundant data, provide backup information to each other which results in a highly advantageous psychological state.

Flight studies examining the head-up concept tested the Computing Devices of Canada, Ltd., Spectocom Display for use as a total IFR helicopter display. It was revealed that insufficient heading information for helicopter IFR approaches was presented with the standard display. With the addition of this information, in direct or indirect form, performance on a landing approach to a 50 ft. break out was adequate.

Improvement in performance, both simulated flight and actual flight, was realized to varying degrees in all studies of this contract. Details may be found in the technical reports referenced.

VII. REFERENCES

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13. ABSTRACT This report covers work performed by Bell Helicopter Company for the Joint Army Navy Aircraft Instrumentation Research Program under Contract Nonr 4429(00). The contract work was initiated May 1, 1964, and terminated February 28, 1966. Under this contract, studies were performed in both the flight simulator and the helicopter.

The simulator studies were oriented about improvement and information augmentation of the contact analog. They were performed in the JANAIR/Bell Dynamic Flight Simulator and examined pilot performance as a function of: (1) the use of director symbols and changes in grid texture, (2) presentation of flight information on vertical tapes, (3) the use of digital readout of flight information.

Flight studies examined the Spectocom Head-up Display and television in flight situations in the JANAIR research helicopter. Recommendations for solution to these problems are presented in the correspondingly appropriate technical reports.

Technical reports of all researches performed under this contract have been issued and are reviewed in this document.

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